AUTOMATIC CATEGORY SEARCH AND ITS TRANSFER AUTOMATIC PROCESS SEMANTIC FILTERING

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Automatic Category Search and Its Transfer:
Automatic Process Semantic Filtering

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Abstract

When subjects receive extended practice searching for words from a consistently mapped (CM) category, search becomes substantially faster, more accurate and less effortful. The present experiments examine the extent to which category search practice effects are semantically based. Experiment 1a examined improvements in reaction time in detecting words from a category as a function of the number of exemplars (4-12) in the category. All conditions showed improvement but there was no effect of the number of exemplars. Experiment 1b examined the extent to which training on a subset of exemplars transferred to untrained members of the category. Results showed substantial positive transfer (60-92%) to untrained exemplars from the trained category and the transfer was better if there were more exemplars in the training set. Experiment 2a replicated previous results showing that practice reduces resource sensitivity in consistently mapped (CM) category search but does not benefit variably mapped (VM) category search. Experiment 2b examined whether untrained exemplars of a CM trained category would be detected on first presentation when subjects were engaged in a high workload VM digit search task. Untrained exemplars of the CM category were detected on first presentation showing substantial positive transfer (70%). We conclude that effects of CM category search practice take place at the category level and suggest that practice results in context activation of the category node. This context activation hypothesis is evaluated with respect to major phenomena relating to automatic and controlled processing.

Automatic Category Search and Its Transfer:
Automatic Process Semantic Filtering

This paper examines how well training to consistently search for a subset of elements of a category will transfer to other elements of the category. It addresses the issue of whether learning in a search task is specific to the trained elements of a category or is generalized to the other elements of that category. For example, when training someone to detect names of animals, to what degree does training to detect the words "cat", "elephant", and "cow" improve your ability to detect words such as "bear"? An applied example of this issue might be how well a medical intern could learn to attend to all the elements of a well defined symptom category representing a given disease after being exposed to only a subset of the elements of that category.

In addition to examining transfer of category search training, this paper proposes and details a hypothesis that situational context can semantically filter input. The hypothesis proposes that if a subject consistently attends to a class of stimuli (e.g., digits) in a salient situational context, the context will bias the subject to focus attention on the previously attended stimuli. For example, after consistently searching for digits in a given experimental environment, subjects have great difficulty ignoring digits when they are present in the visual field but irrelevant to the task (see Shiffrin & Schneider, 1977, Experiment 4d). We propose that the context activates an attentional filter which can selectively pass information into short-term memory on the basis of semantic features.

The present search experiments examined transfer of automatic category search in a consistently mapped search paradigm. When discussing visual search results, it is important to distinguish between two major classes of visual search effects. The classes of effects are based on the relationship between the target and distractor set and the amount of practice (see Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). One class, varied mapping (VM) effects, occurs when subjects cannot consistently attend to stimuli across trials. For example, a particular stimulus that was responded to as a target on one trial might be a distractor on the next trial and vice versa. Hence, a subject's response to a given stimulus varies across trials. The other class, consistent mapping (CM) effects, occurs when subjects receive extensive training and can attend consistently to stimuli across trials. For example, whenever a given stimulus occurs it is always attended and responded to and never ignored.

The reason for differentiating the two classes of effects is due to the quantitative as well as qualitative differences between VM and CM search performance (see Shiffrin & Schneider, 1977; Schneider, Dumais, & Shiffrin, in press). The processing that occurs in VM paradigms will be referred to as controlled processing. Controlled processing is characterized as slow, serial, effortful, and capacity limited. Controlled processes are under direct subject control and are used to deal with novel or inconsistent information. Asymptotic controlled processing performance is achieved with little training. The processing that occurs in CM paradigms is referred to as automatic. Automatic processing is characterized as fast, parallel, fairly effortless processing that is not limited by short-term memory capacity. Automatic processes allow performance of well developed skilled behaviors and requires extensive training

to develop.

Fisk and Schneider (in press) examined word and category search in both CM and VM search paradigms. VM search showed little improvement with practice, and exhibited a linear, self-terminating, slow comparison process (200 msec per category comparison). However, CM word and category search resulted in substantial practice effects. The category comparisons slope dropped from 200 msec to 1.7 msec. In addition, Fisk and Schneider (in press) reported an experiment where subjects performed a serial recall digit-span task concurrently with CM or VM category search. Subjects in that experiment could search for four CM categories and perform the digit span task without a decrement in either task. However, VM category search, for just a single category, resulted in a substantial (26%) dual task category search deficit. Those results suggest that CM category search parallels the costless CM character search results reported by Schneider and Fisk (1982a).

An unresolved issue, in regard to previous category search studies, is the extent to which training on specific exemplars of a given category generalizes to non-trained elements of that category. This is an important issue for two reasons. First, high transfer would provide fairly conclusive evidence that the previous results of Fisk and Schneider (in press) were in fact due to category search, not simply rapid learning of the individual elements of the category. Second, high transfer would indicate that the processing benefits associated with automatic processing (e.g., fast, parallel, not short-term memory limited) can develop for classes of behaviors, not just single instances. The lack of such transfer would suggest that automatic processing would be uncommon for either identifying complex categories or responding to classes of complex events. If there is no transfer to untrained members of a category, then each exemplar of a category would have to receive substantial training (e.g., 200 trials) before the total category could be automatically processed. Learning to detect a complex category, such as animals, with thousands of exemplars would require perhaps millions of trials if learning a subset of animal exemplars did not substantially transfer to processing of other animals.

Previous CM category search results suggest that processing is semantic in nature with high transfer to untrained exemplars. Neisser and Beller (1965) examined visual search performance when subjects were searching for large categories (proper names - 514 names, and animals - 114 words). Subjects were never given the explicit exemplars they were searching for. Their search time declined about a third during fifteen days of practice. New exemplars of the trained category were introduced on the twenty-sixth day. The new exemplars, which had never been seen in the experiment, were detected at the same error rates as previously detected exemplars. Grabol (1971) examined how well subjects transferred a skill developed for detecting CM proper names printed in upper case to the same names printed in lower case. Changing to lower case letters slowed down search only slightly. These visual search results suggest that CM category search is not based on the physical features of the stimuli.

The goal of the present research was to evaluate the extent to which practice at detecting exemplars of a taxonomic category would transfer to other untrained exemplars of that category. Our experiments examined transfer when subjects were trained with a relatively small number of exemplars (four to eight) using both a reaction time and dual task detection performance to measure

transfer. A related question addressed by the following experiments was whether search performance improves as a function of: 1) detections at the higher-order category level; or, 2) the number of times the particular elements of the category are detected.

We used three measures to identify the locus of the CM category search improvement. First, we examined category search improvement as a function of category size. In Experiment 1a we examined performance improvement across categories of varying sizes (4, 8, & 12 exemplars). If search improvement is due to learning the visual features of individual words, then the performance improvement as a function of trials for a category of size 4 should be faster and more pronounced than for categories of sizes 8 and 12. However, if improvement is due to learning at the category level, then there should be little or no difference in improvement rate across the three category sizes.

Second, we examined transfer to untrained exemplars of the trained categories in a reaction time task (Experiment 1b) and a dual task detection task (Experiment 2b). If learning is word based, then there should be little or no transfer to other words of the category. If search improvement is category based and each word of the category activates the category equally, then there should be good transfer independent of the size of the training set. However, if learning is based on the semantic features activated by a word and there is some variance in the features activated across words, then differential transfer should occur as a function of category size. This would be expected if category learning requires the activation of many of the features of the category. If the category size is very small (e.g., 2 words) subjects may learn only a small set of the category features and hence show little transfer to other members of the category. Omohundro and Homa (1981) trained subjects to categorize sets of random dot forms. They found that training subjects with more exemplars (3 versus 9) results in faster classification of novel objects from the trained category.

In Experiment 2a (the training for 2b) we tested the previous finding of Fisk and Schneider (in press) that CM category search requires little or no resources for accurate performance. The dual task paradigm used in Experiment 2a was designed to preclude the switching time potentially available in the design used by Fisk and Schneider (in press).

Experiment 1a - Varied Category Size

The present experiment examined the development rate and asymptotic performance level of automatic processing in CM category search as a function of the number of words included in a category search set. The words used were of high dominance from taxonomic categories that subjects would be expected to have learned in normal word usage. We will use the term "category size" to refer to the number of exemplars (of the given category) to be searched for in the experiment.

Method

Subjects. Eleven subjects from the University of Illinois introductory psychology subject pool participated in the experiment. Their participation

partially fulfilled a course requirement. All subjects were female, reported English as their native language, had normal or corrected to normal vision, and were right handed.

Procedure. The subjects performed a visual search task. Subjects were presented a memory set that contained a taxonomic category label (e.g., Weapon). After pushing an initiation button, subjects saw three vertically placed fixation dots for 500 msec followed by the probe (or test frame) display. The probe was displayed for a maximum of four seconds or until the subject responded. The probe display consisted of three words presented in a vertical column (separated by .93 degrees visual angle). A target (that is, a word from the category displayed in the memory set) appeared on every trial. The subject's task was to quickly determine the target's location in the display (either top, middle, or bottom position) and push the appropriate button on her response box. The three response buttons were placed in a vertical column (a one-to-one stimulus to response mapping). To illustrate, the subject would see the category label Weapon, push the initiation button, see the focus dots, then see the words Bed, Pine, and Rifle, and respond by pushing the bottom response button. The subjects were encouraged to respond quickly but to keep error rates low.

The subjects were provided with three performance feedback cues. 1) On correct responses, a random dot pattern would appear to spin off the screen from the target's display location. 2) Error feedback consisted of a 2 sec tone given through the subject's headset and the display of the actual target word. 3) Subjects were also provided with an indication of their cumulative accuracy. The feedback procedure was used to facilitate motivated performance over the thousands of trials in this and the following experiment.

Design. The primary independent variables were: 1) consistent and varied mapping between the target and distractor words (and therefore category structure) and 2) the size of the CM categories (either 4, 8, or 12 exemplars). The independent variables were manipulated between trials in a within subject design. Each block consisted of 28 trials (7 trials per condition). The subjects completed 70 blocks (1960 trials, 490 trials per condition). The primary dependent variables were reaction time and accuracy.

The subjects were run in groups of two or three. Each subject's display was independent of the others. Subjects participated in one 45 minute session per day for three consecutive days.

Stimuli. Three categories (Four-footed animals, Human body parts, and Colors) were used as CM categories. The size of each category (either 4, 8, or 12 exemplars) was counterbalanced across subjects. For example, the category of Colors contained 4 exemplars for one-third of the subjects, 8 for another one-third, etc. There were four categories used as VM categories. The VM category words were targets on VM category search trials and used as distractors on VM and CM trials. Subjects were not aware of CM/VM distinction. The VM categories were Articles of Clothing, Weapons, Furniture, and Trees. All VM categories contained four exemplars. The words used for all categories (CM and VM) were from three to six letters in length and all had high item dominance rankings in the Battig and Montague (1969) norms (ranking from 1-15). The letters making up the words were upper case and constructed from dots on a

rectangular grid 32 dots wide by 48 dots high. The characters subtended .43 degrees in width and .62 degrees in height. The refresh rate of the dots making up the stimuli was 10 msec. The room was dimly lit (.4 foot candles [.43 lx] incidental light) with the dots easily visible on the display (.005 foot lamberts [.017cd/m^2] per dot). The subjects sat 46 cm from the display. In a given word, each letter was separated by .3 cm (.37 degree visual angle). The distance between each word was .75 cm (.93 degree visual angle).

Equipment. The experiment was computer controlled. The computer was programmed to present the appropriate stimuli, collect responses, and control timing of the display presentation. The stimuli were presented on Tektronix Model 604 and 620 cathode ray scopes which contained P-31 phosphors. Each subject wore a headset through which white noise and the error tone were carried.

Results

The reaction time data from Experiment 1a are presented in Figure 1 as a function of practice. The first 35 trials per condition (blocks 1-5) were excluded from the analysis since during this time subjects were still trying to orient themselves to the task. Analyses of the simple main effects of practice (trial blocks 6-70) showed that all CM conditions significantly improved with practice (p < .0005 in all cases). VM performance, however, did not improve over trials [$F(12,120) = 1.59$, $p > .1$]. The comparisons between conditions showed that none of the CM conditions differed from each other (Fs < 1) while all CM conditions differed from the VM condition (p < .000) in all cases). The linear trend for the reaction time improvements per 100 training trials was 23.6, 19.4, and 17.6 msec for CM categories of 4, 8, and 12 exemplars. All of the CM linear trends were significant (p < .01). The VM improvement per 100 training trials was 10.2 msec which was not significant (p > .05). The error rates for CM conditions were 2.6, 3.2, and 3.1% for categories with 4, 8, and 12 exemplars and 5.7% for the VM condition. A discussion of these data will be combined with the discussion of Experiment 1b.

Insert Figure 1 about here

Experiment 1b - Reaction Time Transfer

In the next experiment we examined transfer to untrained exemplars from the categories of size 4 and 8 that were trained in Experiment 1a. Since we were restricted to words of three to six letters length, we excluded the category of size 12 from the test of transfer due to a lack of good exemplars for transfer.

Method

Procedure. The procedure was the same as Experiment 1a except that the new categories were used as VM distractors and new CM target words were presented. Subjects were informed that new words would be appearing that had not occurred during Experiment 1a. However, subjects were not informed that new words from their trained CM categories would appear.

__Design__. The independent variables in the present experiment were: 1) The relationship between the target and distractor stimuli being either consistent or varied; 2) Type of consistently mapped stimuli being either trained exemplars from a trained category (designated as Train(n) where n refers to the trained set size). Untrained exemplars from a trained category (designated as Transfer(n) where n refers to the trained set size), or exemplars from a New category. There were 42 trials per block (7 trials per condition) and subjects completed 55 blocks (2310 trials) in three sessions.

__Stimuli__. To avoid the confounding of distractor learning (see Dumais, 1979; Kristofferson, 1977) new VM categories were used for VM search and for distractors during CM search. The new VM categories were three of the following: Natural earth formations, Units of time, Weather phenomena, and Kitchen utensils. One of these categories (counterbalanced across subjects) was used as the New CM category. The VM and New CM categories each contained six exemplars. The trained CM categories were the subjects' previous size 4 and size 8 categories. Each of the previously trained CM categories were increased to 12 exemplars (8 and 4 untrained exemplars for the previous size 4 and 8, respectively). In all other ways the present experiment was the same as Experiment 1a.

__Subjects__. The 11 subjects who participated in Experiment 1a were paid for their participation in the present experiment.

__Results__

The data from Experiment 1b are presented in Figure 2. The data are presented as a function of practice. The linear trends for reductions in reaction time per 100 trials were 5.3 and 5.0 msec for the Trained(4) and Trained(8) conditions which were nonsignificant ($p > .05$). The linear trends for Transfer(4), Transfer(8) and New categories were 16.8, 15.8, and 22.5 msec per 100 trials which were significant ($p < .01$). The VM condition reaction times had a slight, nonsignificant, __increase__ in the linear trend per 100 trials of .6 msec. The error rates were 1.9, 1.6, 3.0, 2.0, 3.6, and 6.5% for Trained(4), Trained(8), Transfer(4), Transfer(8), new CM, and VM conditions respectively, paralleling the reaction time data. The VM data show periodic fluctuations across trials (see Figure 2). The peaks in these curves appear near the end of sessions. This effect is probably due to session warm up and/or fatigue since VM performance has been shown to be susceptible to vigilance decrement (Fisk & Schneider, 1981). The comparison between the Trained(4) and Transfer(4) conditions did reach significance [$F(1,10) = 7.68$, $p < .02$]. The Trained(8) and Transfer(8) conditions did not differ ($F < 1$). The Transfer(4) and Transfer(8) conditions were both superior to the New category condition, [$F(1,10) = 12.93$ and 36.59, p's $< .005$; respectively]. In addition, the New category performance was superior to the VM category performance [$F(1,10) = 10.93$, $p < .01$].

Insert Figure 2 about here

__Discussion - Experiments 1a and 1b__

The data from both experiments support the hypothesis that the learning in perceptual search can be at the category level. From Experiment 1a we can infer that it is possible for automatic search to develop as a function of consistently mapped detections at the semantic category level, rather than as a function of the number of times the individual exemplars themselves are detected. This inference follows from the fact that the performance improvement rate and asymptotic level are equivalent across the set sizes of the CM trained categories (see Figure 1). Another indication that learning is at the category level is the large CM 12 versus VM differences at the end of Experiment 1a. Subjects had detected each CM 12 word a maximum of only 41 times by block 70, but the reaction time was 160 msec faster than VM. We typically found little CM/VM difference in a word search reaction time experiment with only 40 detections. By block 70 subjects had received 490 searches for the category. That number of CM searches would produce substantially faster reaction times. The large reaction time improvement with few detections per word suggests that the learning is taking place at the category level.

Experiment 1b demonstrated that CM training on a subset of exemplars from a semantic category transfered to untrained exemplars of that category. Learning can occur at a higher-order semantic level in the absence of repeated stimulus-response pairings of __particular__ stimuli. The transfer to new items of the untrained set is very high. Figure 3 presents the reaction time for the first five blocks (approximately 9 trials per word). The mean reaction time was 778 msec for the Transfer (8) words, 756 msec for the Trained(8) words, and 934 msec for the new category words (approximately 6 trials per word). If we use as a measure of transfer the relative improvement [(New category - Transfer(8))/New category - Trained(8)] the transfer was 92%. (Note however, Transfer(8) and Trained(8) did not differ statistically.) In the Trained(8) condition subjects had had approximately 61 exposures to each word in initial training and this resulted in only a 13 msec benefit over the transfer category items, whereas category training resulted in a 156 msec benefit for the Transfer(8) items over new CM items and a 233 msec advantage over VM search.

Insert Figure 3 about here

The statistically significant difference between the Trained(4) and Transfer(4) suggests that training with small sets (potentially 4 items or less of a semantic category) reduces transfer or increases learning of individual words. The relative improvement in the Transfer(4) condition was 60% whereas in the Transfer(8) condition it was 92%. There are three potential interpretations for this lower transfer. First, with only four items subjects may have tried to recall the set and maintain the items in memory. Thus, the search may have been partially a word search and partially a category search. Second, the automatic category activation may develop as the words activate the total set of features of the category. For example, the category of earth formations represented by eight words would have more features in common with the remaining words in the category than would the category represented by only four words. When subjects learn to classify new abstract categories, generalization to novel stimuli in the category improves if subjects train with a greater number of patterns (see

Omohundro & Homa, 1981). The third possible interpretation is that in category search both word and category learning occur. Since subjects had 123 detections per Trained(4) word during Experiment 1a this could have improved the word level processing as well as the category processing. The difference between the Trained(4) (730 msec) and Trained(8) (765 msec), though nonsignificant, is suggestive of some word based learning.

The present lack of practice effects in VM category search results replicate the previous letter search (Kristofferson, 1972; Shiffrin & Schneider, 1977; Schneider & Fisk, 1982a,b) and category search results (Fisk & Schneider, in press). In Experiment 1a there is no evidence for any benefit of practice after the first session (Figure 1 approximately trials 175 to 455). VM reaction time increased from 937 msec for the last blocks of Experiment 1a to 1011 msec in 1b. Experiment 1b shows within-session variation but no practice effects across sessions. We interpret the approximately 10% slowing in VM reaction times between VM Experiments 1a and 1b as due to the use of different categories.

The high transfer effects observed in Experiment 1b can not be interpreted as being due to slower learning in new CM category conditions. The average linear trend for the CM conditions in Experiment 1a was 20.2 msec reduction in reaction time per 100 trials, relative to 22.5 msec in the New CM condition in Experiment 1b. The difference between VM and CM for trials 35-70 was 99 msec for Experiment 1a, and 96 msec for Experiment 1b.

The present results replicate the positive transfer effects in category search observed by Neisser and Beller (1965). They found no statistically significant differences between trained and transfer words when the new transfer words were introduced on the twenty-sixth day. In the present experiment after only three sessions of training with only 490 searches per category, we also found no statistically significant differences between trained (8) and transfer (8) words. Neisser and Beller (1965) trained with a search set of at least 100 exemplars. We observed similar positive transfer effects when we trained with a set of only eight exemplars. For well defined semantic categories, category search experience for a modest number of training trials (i.e., 490) with a modest number of exemplars (i.e., 8) results in substantial positive transfer (i.e., 92%) to untrained exemplars.

Experiment 2a Dual Task Training

The previous experiment showed high transfer of CM category search training in a reaction time task. The present experiment examines whether exemplars from a CM trained category "pop out" and are accurately detected when subjects are engaged in a high workload task. This experiment provides a replication of a dual-task category search experiment reported by Fisk and Schneider (in press). The use of a dual-task procedure is important because one of the major defining characteristics of automatic processing is that it can be done with little attentional resource cost (see Shiffrin, Dumais, & Schneider, 1981).

One way in which to demonstrate the existence of an automatic process is to consume the subject's controlled processing resources with a resource limited controlled processing primary task and assess performance on a task treated as a secondary task. This is done with dual-task paradigms. Little or no dual-task decrement is expected if the secondary task is performed as an automatic process; however, a substantial dual-task decrement is expected if the secondary task must be performed via a controlled process.

In the present experiment subjects performed a VM digit search task that required searching twenty frames, each of which contained two digits, for the occurrence of target digits. Subjects pushed a button indicating the position of any digit that matched one of the two digits maintained in short-term memory (a memory set size two, frame size two search). The frames were presented fast enough so that accuracy was resource limited (i.e., if subjects devote search resources to other tasks, digit search performance declines, see Schneider & Fisk, 1982a). Subjects' VM digit accuracy and category detection ability were assessed in both single-task conditions and in dual-task conditions (i.e., digit search and concurrent secondary task category search). If subjects' dual task VM digit performance approaches the single task level, the dual-task category search performance is assumed to reflect performance in the absence of controlled processing resources. If subjects' dual-task VM digit search performance approaches the single task level, it is assumed that the category search performance reflects category search ability when little or no resources are allocated to the category search task. In either case (i.e., equivalent or approaching equivalent single/dual primary task performance) the dual-task paradigm measures the sensitivity of CM and VM category search to resource withdrawal.

In Experiment 2a we trained subjects to detect CM category words while controlled processing resources were allocated to the VM digit task (VM category search was similarly assessed). Experiment 2b examined the CM detection ability of non-trained words that were members of the CM category trained in the present experiment.

Method

Subjects. Six students (three females) from the University of Illinois were paid for their participation. All subjects reported English as their native language and had normal or corrected to normal vision. One of the subjects was left handed.

Procedure. The subjects' task was to detect the occurrence of target digits, exemplars from an indicated category, or both digits and category exemplars depending on the search condition. A representation of a dual task trial sequence is presented in Figure 4. On each trial, the subjects were presented their average percentage for detection accuracy in the given trial block. This accuracy feedback was displayed for one second. In the single task conditions, this feedback indicated either the digit or category search detection accuracy. In the dual task conditions feedback was provided only on the digit detection task. This was done in order to encourage subjects to maintain digit task performance (c.f., Schneider & Fisk, 1982a). After the feedback display, the memory set was displayed until the subject pushed the initiation button. Thereafter, a central fixation dot was displayed for 500 msec. Then, two frames (400 msecs each) of X's and Y's in all display locations were presented to facilitate proper fixation. The actual trial frame sequence consisted of 20 frames each presented for 400 msec. Each frame consisted of

four characters (two digits and two random dot patterns) positioned to form a square around a centrally displayed word. The digits were first presented on one diagonal of the square then the other, *alternating on a frame by frame* basis. The same word was displayed on two successive frames (display time of 800 msec). There was always a two second blank period at the end of the frame sequence to allow sufficient response time if a target occurred on late frames.

Insert Figure 4 about here

The subjects initiated each frame sequence with a button *push using the* index finger of their nonpreferred hand. In the lower portion of the response box were five buttons -- four buttons formed a square and one was placed to the right of the other four. Subjects responded to the detection of a digit by pushing one of the four buttons corresponding to the display location of the digit (e.g., if the target was detected in the upper left display position of the square the subject would push the upper left button). They indicated a detection of a target category exemplar by pushing the single right-most response buttons. Each subject responded with the index finger of his/her preferred hand.

Subjects were given up to 4 seconds to respond after a target and have that response recorded as a correct detection. Any response not within that time window was recorded as a false alarm. The subjects could only have one hit per *hit interval; any other response* within the hit interval was recorded as a false alarm.

__Design__. There were three primary independent variables: type of search, number of targets, and type of targets. With respect to the type of search task, there were three single task conditions and two dual task conditions. The single task conditions consisted of: a) single task digit search -- subjects were presented a two digit memory set and required to search for the occurrence of either digit (digits were variably mapped); and b) single task category *search -- subjects were presented a category label* (either a CM or VM category) and required to search for words from the specified category. On dual task trials subjects were presented both a two digit memory set and a category label (either CM or VM depending on the condition). Subjects were required to detect the occurrence of target digits and category exemplars (target digit and category exemplars never occurred together, see above). Digit detection was the primary task.

The second independent variable was the number of targets presented. During a *trial either 0, 1, or 2 targets were presented. The number of targets* per trial was randomly determined with the restriction that each target probability occur on 33% of the trials. The target location(s) within a frame sequence was randomly determined with the restriction that if two targets occurred, the lag between the first and second target was at least 4 seconds (subjects were unaware of this restriction). The type of targets presented was also varied on dual task trials. On dual trials, 33% of the trials contained no target, 22% contained one digit and one word, 22% contained either one digit or one word, and 22% contained either two digits or two words. Note that no more than two targets could occur *during a given trial*.

__There were two types of category search__. Category search was manipulated between trials for the first four replications and between blocks for the last four. *The between block manipulation of category search was utilized to* encourage subjects to maintain digit performance during CM search.[1] Subjects completed four replications where the category search was a between trial CM/VM manipulation. A complete replication of conditions in this first part consisted of one block (36 trials) of single task category search, one block of single task digit search, and 3 blocks of dual task digit/category search. The subjects completed four replications (20 blocks) of this condition. Next, the subjects participated in a between block CM/VM category search. A complete replication of this condition consisted of one block each (18 trials per block) *of single task CM and VM category search, one block of single task digit search,* two blocks of dual task digit/CM category search, and two blocks of dual task digit/VM category search. Again, the subjects completed four replications of this condition in four sessions.

__Training__. Prior to participating in the dual task experiment, subjects were given single frame training following the same general procedure as Experiment Ia. The subjects completed 3510 trials (1755 CM trials) in seven or eight 45 minute sessions. This training was provided to facilitate automatic *processing development prior to performing the dual task. At the end of the* single frame training there was a 168 msec difference between the CM and VM category search conditions (2% and 4% errors for CM and VM respectively).

__Stimuli and equipment__. One category (either Human body parts or Colors) was used as CM categories for a given subject. Each CM category contained eight exemplars. The VM categories were: Weapons, Trees, Clothing, and Furniture. The VM categories each contained six exemplars. The choice and construction of the stimuli and equipment were the same as the previous experiments.

Results

Figure 5 presents the category word detection performance under single and dual task conditions. In the single task conditions subjects performed just the word search or just the digit search tasks. In the dual task conditions subjects performed both the digit and word search tasks with instructions to protect their digit search performance. On the first replication both CM and VM dual task performance declined substantially (45% and 49% respectively) relative to the single task performance levels. The primary task VM digit detection performance (Figure 6) also declined substantially on replication 1 (26% and 29% digit decrement during CM and VM category search, respectively). Switching search category conditions from between trial (replications 1-4) to between block (replications 5-8) had little effect on category search performance or practice effects.

Insert Figures 5 & 6 about here

The dual task CM category search performance improved substantially with practice, reaching ceiling on the eighth replication (Figure 5). The dual task digit detection with CM word search was substantially below the single task performance level but improved with practice. *In the last replication (in which*

the category search condition was manipulated between blocks) the CM dual task digit deficit was 11% (nonsignificant, $t(5) = 1.96$, $p = .08$) with CM category detection deficit being only one percent.

For the last replication, the dual task VM category search performance was 61% below the single task performance level. Dual task VM category search performance did not improve with practice; the VM dual task search deficit was: 49%, 56%, 52%, 58%, 59%, 54%, 50%, and 61% across replications one to eight, respectively. The dual task digit detection with VM category search did improve with practice for the first four replications but remained stable for the last four. On the last replication, the dual task digit detection with VM was 17% (significant $t(5) = 2.56$; $p < .05$ one tailed test) below the single task level and 5% below the dual task CM level (nonsignificant $t(5) = .50$).

Discussion.

The present data clearly show the insensitivity of CM category search to withdrawal of resources. Performance on VM category search, however, deteriorates dramatically when resources are withdrawn. The VM deterioration is not reduced with practice. The small deficit in digit detection accuracy, when performed concurrently with CM category search, probably reflects a bias in the subject's resource allocation strategy. The present (nonsignificant) decrement in CM primary digit task performance may be due to subjects' tendency to "waste" resources on the CM search task (see Schneider & Fisk, 1982a for discussion). Subjects have a strong tendency to divide resources between tasks even if such a division reduces primary task performance and does not benefit the secondary task.

Clearly, accurate CM category search is possible with a small cost in primary task performance. It is unclear, given the present data, whether differential training (such as CM/VM training between sessions or days) or simply more training might result in no resource cost associated with CM category search. In a replication of Experiment 2a (Schneider & Fisk, Note 1) six out of eight subjects could perform the category search and the concurrent digit search with less than a 5% decrement in digit search performance.

These results replicate the previous finding of Fisk and Schneider (in press) that CM category search becomes insensitive to resource withdrawal. The present results replicate the previous results showing no VM dual task improvement with practice with both letter search tasks (Schneider & Fisk, 1982a) and category search tasks (Fisk & Schneider, in press). The present experiment utilized the VM digit search as a concurrent task whereas the Fisk and Schneider (in press) experiment utilized a short-term memory encoding task. Also in agreement with previous studies this experiment showed that substantial dual task practice and subject dedication are required before the CM processing occurs at little or no cost. The improvement in dual task CM category search (Figure 5) is probably due to subjects' learning to enable category search in the dual task conditions (see Schneider & Fisk, 1982a, and below). Subjects generally require several sessions of practice at performing dual task conditions to enable accurate CM search. In addition, it takes subjects several sessions to learn not to divide resources between the CM category and VM digit tasks but rather to allocate all the resources to the VM digit task. In fact, the smooth CM dual task improvement in Figure 5 is due to summing over

relatively sharper improvement functions occuring at different times for individual subjects. One subject commented that he had a great deal of difficulty with the dual task until he "let go" of trying to detect the CM items and just let them "pop out".

Experiment 2b -- Dual Task Transfer

The final experiment was conducted to examine the issue of transfer to untrained category exemplars (from the trained category) while the category search was performed by automatic processing (since processing resources were consumed for the VM digit task). The RT measure used in Experiment 1b would lead us to conclude that, for the Transfer (8) condition, there is near perfect (92%) transfer to untrained exemplars of a trained semantic category. The present experiment examined how well subjects could detect words that were untrained but were members of the trained category. In particular it examined how well these words could be detected while subjects were engaged in the high workload VM digit search. In essence the question was whether or not untrained words would "pop out" and attract attention because they were members of the trained CM category.

Method

Subjects. The six subjects who participated in the dual task in Experiment 2a participated in the current experiment.

Design. There were 5 search conditions in this experiment requiring the subjects to search for: 1) *Trained exemplars from the trained CM category;* 2) Untrained exemplars from the trained CM category. (Note, the distinction between 1 and 2 was not made apparent to the subjects. That is, if they had searched for Colors as their CM set, they would be presented Color in their memory set -- if a target occurred it could be a trained or untrained Color exemplar; subjects were not told that new exemplars of the trained category would occur.) 3) The new CM category condition required subjects to search for a new category which was counterbalanced across subjects with the VM categories. 4) The counterbalanced new CM condition examined performance on a category used as the trained CM category for other subjects (i.e., subjects which had "colors" as a trained CM category had "body parts" as a counterbalanced CM category and vice-versa). 5) The VM search condition required subjects to search for one of three VM categories. The VM categories (and therefore the distractors) were changed to eliminate possible confounding of distractor learning (see Dumais, 1979; Kristoffersen, 1977).

All trials were dual task trials. The search conditions were manipulated between blocks of trials yielding four blocks per replication (because conditions 1 and 2 were a within block manipulation). As in the previous experiment, there were 18 trials per block. In blocks where subjects searched for the trained CM category, targets were randomly selected from trained exemplars (Condition 1) and untrained exemplars. Subjects completed two replications of search conditions in one session.

Materials. The words for the new categories were chosen from the Battig and Montague (1969) norms in the manner outlined in the previous experiments. Each VM category contained 6 exemplars; the New CM categories contained 4

exemplars. There were 4 untrained exemplars from the trained CM category. The VM and New CM categories (counterbalanced across subjects) were: Weather phenomena, Earth formations, Kitchen utensils, Four-footed animals, and Time.

Results

Category detection accuracy is presented in Figure 7. There were no significant differences in category search performance among the three control conditions (i.e., the new CM, counterbalanced CM, or VM search conditions). False alarms were extremely rare (never more than .1%) and were not systematically related to any condition. In regard to the issue of transfer, the untrained CM exemplars were detected significantly better ($p < .01$) than the new CM, counterbalanced CM, or VM categories. The observed detection rate for new exemplars for the trained categories for the individual subjects was 50, 70, 87, 90, 93, and 100%. The mean was 81.67% and the median 88.5%. The median d' for detecting transfer words (assuming .1% false alarm rate) would be 4.29. Subjects exhibited an extremely high criterion (estimated B of 57.5). Mean d' and B were 4.53 and 62.81, respectively. If we estimate the no transfer detection accuracy to be 48% (i.e., the mean of the New category, new counterbalanced category and VM category conditions) the untrained exemplars showed a 72% transfer [(transfer CM - estimated no transfer)/(trained CM - estimated no transfer)]. The median transfer was 81%. The detection performance of the untrained CM exemplars was significantly worse (16%,; t = 2.108, p <.05 one tailed test) than the trained CM exemplars, indicating less than perfect transfer.

Insert Figure 7 about here

Considering primary task digit search performance, the difference between conditions on the category search measure was not due to differential primary task trade-off. Digit detection on trials where subjects searched for Untrained exemplars from their trained CM category was 86.5. This was 5.6% less than the previous (Experiment 2a) single task performance (There was also a 6% digit detection deficit when subjects searched for the trained CM category exemplars). Digit detection accuracy was 81% (12% decrement from single task performance) when subjects search for "New category" words, 84% (8.3% decrement) during counterbalanced CM category search trials, and 83% (9.4% decrement) during VM category search trials.

Discussion

The purpose of this experiment was to determine whether new exemplars from a previously trained CM category would be detected on the first presentation while subjects were under high workload. In replication 1 of Experiment 2b, subjects were presented each untrained exemplar an average of 2.25 times. Subjects detected an average of 82% (median 88.5%) of these new words while showing only a 5.6% decrement in simultaneous VM digit search (relative to the single task digit performance in the last four replications in Experiment 2a). In contrast subjects detected less than 50% of the new CM or VM category words with an average 10.15% decrement in simultaneous VM digit search. As in Experiment 1b, Experiment 2b shows that CM training on a subset of category

elements shows substantial positive transfer to other elements of that category. It should be noted that subjects were not informed in advance that new CM words would appear. In general, all subjects were aware that the new words from the trained category were novel and subjects were surprised by their occurrence. Some of the fall-off in performance on the very first presentation of a transfer word might have been caused by the surprise and subjects' being unsure whether to respond or not.

The difference between the present degree of transfer and that of Experiment 1b probably reflects a difference in response criterion. Subjects who participate in automatic/controlled processing dual task experiments, designed in a manner similar to the present dual task, typically become highly conservative in their responding to the secondary automatic task (see Schneider & Fisk, 1982a). Also, in Experiment 1b a target was presented on every trial whereas in the present experiment targets occurred in a quasi-random fashion. The differential target probability, coupled with the tendency to respond more conservatively (median Beta of 62.81) in dual task paradigms, may account for the differential transfer observed between Experiments 1b and 2b.

The lack of a significant difference between the new CM conditions and the VM conditions (conditions 3-5, Figure 7) was expected due to the small number of trials in the CM conditions. During Experiment 2b subjects experienced an average of only 7.9 detections of words of the categories and these were all while the subjects were in dual task conditions. We would expect CM performance to improve with practice but many more trials would be required before reliable differences would be expected (e.g., as in Experiment 2a).

There was no change in VM performance as the result of changing VM categories between Experiments 2a and 2b. Dual task VM detection accuracy was 38% on the last replication of Experiment 2a. This was after some 439 single frame training searches, 31 single task and 81 dual task multiple frame searches per category. In Experiment 2b, with a total of only 9 dual task searches per category, detection accuracy was 45%. These results are consistent with previous results suggesting little benefit for VM practice at searching for well known categories (Fisk & Schneider, in press) or VM letters (Kristofferson, 1972; Shiffrin & Schneider, 1977; Schneider & Fisk, 1982a,b).

General Discussion

The present results suggest that the major site of learning in CM category search experiments is at the [illegible]. Experiment 1a measured reaction times for comparing t[illegible] against a single category in memory. The experiment did [illegible] significant VM practice effect but did find significant practice effect [illegible] CM category search. At the end of the experiment CM searches were 163 msec faster than VM searches. The results showed that category learning was independent of the number of exemplars (i.e., 4-12 items) in the trained category. Experiment 1b, also using a reaction time paradigm, showed that after 490 searches for a category, in which subjects detected one of eight exemplars, there was substantial positive transfer (i.e., 92%) to new members of the category. Transfer was measured by comparing the reaction times of new members of the trained categories relative to old exemplars from a trained category and new exemplars from a new category. Experiment 1b also showed that there was better transfer when subjects trained

with eight rather than four exemplars of the category.

Experiment 2a examined detection accuracy and resource sensitivity in a category search task requiring subjects to detect words from semantic categories which were presented every .8 sec. On dual task trials, subjects were required to compare two memory digits to two display digits every .4 sec. The results showed that dual task CM category detection performance improved with practice until single task ceiling performance levels were reached. Subjects were able to detect words from a semantic category while carrying on the digit task with no significant deficit in either condition. In contrast, dual task VM category search showed a substantial decrement in category detection accuracy (i.e., 55%) and a significant decrement in digit detection accuracy (i.e., 17% on the last replication). The results are consistent with previous findings (e.g, Ostrey, Moray & Marks, 1976; Fisk & Schneider, in press) and support the hypothesis that CM category search can be performed at little or no attentional resource cost but VM category search can not.

Experiment 2b showed high positive transfer in a dual task procedure for untrained words from a trained category. New words from the trained category were accurately detected the first time they were presented even when subjects were engaged in a simultaneous digit search task. Experiment 2b also found that changing the VM categories had no effect on dual task VM detection performance.

The results support the hypothesis that automatic processing can activate category level information. The lack of an effect of the number of exemplars and the demonstration of large positive transfer suggest that the learning is at the category level. Subjects' false alarm data also suggest that subjects were processing words to the semantic feature level. In a related experiment with the same subjects, four out of five subjects searching for color words false alarmed to the word "canary". These subjects made no false alarms for any of the other 359 word presentations. The subjects commented that canaries are yellow and were aware they had pushed the button inappropriately. The results suggest that subjects responded to the salient color attribute of "canary", thus supporting the hypothesis that subjects were performing either a category or category feature based search.

The present results showing high positive transfer after CM category search training are consistent with the previous literature. Neisser and Beller (1965) trained subjects to search a large implicitly defined set of proper names (at least 100 exemplars) and then tested detection accuracy for names novel to the experiment. They found that new names could be detected as well as names which had appeared during training. The present experiments showed high transfer when subjects were trained on relatively small sets (eight exemplars) and utilized a reaction time position identification and dual task detection paradigm. The present results are suggestive of better transfer with more exemplars in the training set (Experiment 1b). This is consistent with the results showing that increasing the number of patterns that define a category during category classification results in better transfer to new members of the category in a search task (Homa & Vosburg, 1976; Omohundro & Homa, 1981).

The lack of practice effects in VM search and substantial practice effects in CM search are consistent with the previous literature. VM category search performance did not improve with practice in either single frame category search

(Experiments 1a, 1b), multiple frame single task detection accuracy (Experiment 2a), or dual task detection accuracy (Experiment 2b). This is consistent with the general lack of VM practice effects after the first few sessions found for character search (Kristofferson, 1972; Shiffrin & Schneider, 1977), word search (Fisk & Schneider, in press), and category search (Fisk & Schneider, in press). It is also consistent with the lack of dual task VM practice effects for letter (Schneider & Fisk, 1982a,b) and category search (Fisk & Schneider, in press). The large practice effects in CM search are consistent with the previous letter search (e.g., Schneider & Shiffrin, 1977), word search (Fisk & Schneider, in press), category search (Neisser & Beller, 1965; Grabol, 1971; Ostrey, et al, 1976; Fisk & Schneider, in press), dual task letter search (Ostrey, et al, 1976; Schneider & Shiffrin, 1977; Schneider & Fisk, 1982a,b), and dual task category search results (Ostrey, et al, 1976; Fisk & Schneider, in press). (For a review of these issues see Schneider, Dumais & Shiffrin, in press.)

Site of CM Training Effect

The present results in conjunction with other reports (Shiffrin & Schneider, 1977; Fisk & Schneider, in press; Schneider & Fisk, 1982a, Note 2) allow specification of the memory site of CM practice effects. Previous results have shown that CM practice substantially changes performance (e.g., greatly reducing comparison slopes, reducing resource costs, and reducing subject control; see Fisk & Schneider, in press; Schneider, Dumais, & Shiffrin, in press;Shiffrin & Schneider, 1977). The following discussion uses the current and previous results to identify how CM practice might alter the activation patterns in memory. We will describe each site, and indicate the predicted effect of a change at that site. We then show that the data are incompatible with major changes in any site except one. This analysis suggests that after extended CM training the experimental context will activate target nodes and inhibit distractor nodes. We hypothesize that experimental context produces a tuned filter that can allow fast, accurate, parallel filtering of the input. The following discussion details the sites at which training might influence the activation of nodes in memory to produce the observed differences between CM and VM search and the observed transfer effects.

The framework we have in mind is similar to that proposed by Shiffrin and Schneider (1977). Memory is conceived to be a large collection of interassociated nodes in a generalized graph. Learning is interpreted to reflect changes in the activation strength between nodes. We assume a coactivation strengthening hypothesis that when nodes are simultaneously active in short-term store (STS), the links between the nodes are strengthened. After such strengthening one node will more strongly and quickly activate other nodes which were coactive with it. We also assume that coactivation followed by inhibition of a particular node results in increased inhibition between the activated nodes and the inhibited nodes.

For descriptive purposes we divide nodes into three classes: informational, control, and context (see Figure 8). Informational nodes activate other informational nodes such as the letters "R" "E" "D" activating the word "RED" which in turn activates the category "color". The role of information nodes is to perform stimulus transformations. The second class of nodes are control nodes which influence the activation levels and possibly thresholds of information nodes. Their role is to temporarily bias the system to perform

appropriate information processing tasks (this activation is similar to what Posner & Snyder, 1975, refer to as effortful processing). For example, in a category search for color words, the subject would activate (place into STS) the control nodes for "color category search" and "motor priming" to perform a motor response on category detection. The third class of nodes are <u>context nodes</u>. Context nodes represent all the activations due to the experimental situation. For example, those activations determined by the continuous sensory input, the emotional state of the subject, time of day, etc. The assumed role of context is to bias nodes in memory in a manner similar to that of control process activation. However, subjects are assumed to have relatively little direct control of context nodes and their activation does not consume limited STS capacity (possibly because all the activation is below the STS threshold level).

Figure 8 illustrates the basic activation influences assumed to occur during CM or VM category search. CM practice could result in changes in activation strength between any of the links in the diagram. We will briefly summarize evidence relating to each of the labeled links in Figure 8. Note our discussion relates to practice effects for well defined categories. We believe that under the appropriate experimental conditions all of the links in Figure 8 would change.

Insert Figure 8 about here

A potential site of practice effects could be an increase in strength of links originating from the control process category search node (<u>a</u> and <u>b</u> links, Figure 8). Coactivation in STS of the category search node and the semantic category node might result in the strengthening of the links between these nodes. Every time the category search node and semantic category node were both active in STS, the activation strength of the link between them (<u>b</u> links, Figure 8) would increase. If category search links are substantially strengthened with practice, one would predict substantial benefit with VM practice. With greater activation resulting from the <u>a</u> and <u>b</u> links, less activation would be required from the letter to word and word to category links, producing faster responses. Theoretically, it should be possible to activate different search categories on different trials. However, experiments show that there is little benefit for extended practice in VM search. Shiffrin and Schneider (1977, Experiment 2) found no benefit of extended practice in VM letter search (see also Kristofferson, 1972). Fisk and Schneider (in press) found no benefit for word search practice and only a small reduction in VM category comparison time during 4800 trials of practice.[2] The present Experiments 1a, 1b, and 2a found no VM practice effects. In contrast, Fisk and Schneider found 98% reduction in comparison slope (from 202 msec to 1.7 msec) when subjects trained in a CM category search condition. The small VM practice effects relative to the large CM practice effects suggest that little of the CM category search practice effects can be accounted for by changes in the links from the "category search" nodes.

A second potential site of practice effects could be between word nodes and their semantic categories (<u>c</u> links, Figure 8). Such an increase could reduce the amount of time required for the activation of the word to activate the semantic category node above threshold. If practice changes performance of

these links, one would predict benefits from VM search practice and little transfer to new exemplars from the trained semantic category. However, the present results do not support these predictions. The lack of VM practice effects and the high positive transfer to new words of a trained category indicate that changes in the word to semantic category links cannot account for the CM practice effects. It should be noted that we used words which were high associates of the category. The development of the word to semantic category links may be critical when dealing with novel or poorly defined categories, particularly in VM category searches (see Shiffrin & Schneider, 1977, Experiment 3).

Practice could potentially strengthen links between letters and words, semantic categories and responses, or motor priming and response nodes (links <u>d</u>, <u>e</u>, and <u>f</u>, Figure 8). However as with links a, b, and c this would predict substantial VM practice effects. There were VM practice effects during the first thirty-five trials of the new experiments (see Figure 1). It is unclear whether this was due to subjects' attempting different strategies to initially perform the task or possibly strengthening any of the links in Figure 8. In either case these practice effects occur rapidly and cannot account for the large CM/VM differences.

Practice could increase the strength of links between experimental context and information nodes at all levels (<u>g</u>, <u>h</u>, and <u>i</u> links, Figure 8). The importance of CM training strongly suggests that context activation is a critical factor. The experimental context is not easily modified by the subject. Most of the subject's sensory input, emotional condition, physiological condition, etc., are fairly stable during the course of the session.

By the coactivation hypothesis, consistently attending or rejecting stimuli would enhance target activation and reduce distractor activation. If the subject actively attends to target stimuli within the experimental context, the context would later activate target nodes. If the subject actively compares but then inhibits nodes (i.e., distractor stimuli), the context later inhibits activation of distractor nodes. Repeated strengthening of the target activation and distractor inhibition can account for performance improvements with CM practice. A visual analogy would be that in the experimental context target stimuli are brightened and distractor stimuli are darkened. Consistent with context activation interpretation are results showing strong positive transfer when subjects search for trained CM targets with new distractors (Experiments 1b, 2b; see also Prinz & Atalan, 1973; Dumais, 1979; Shiffrin, Dumais, & Schneider, 1981). In terms of the analogy, trained targets are brightened through CM training and stand out from the background of novel distractors. Consistent with the context inhibition of distractors is the evidence of positive transfer of searching for new targets in trained distractors (Dumais, 1979; Kristoffersen, 1977; Prinz & Atalan, 1973; Shiffrin, Dumais & Schneider, 1981). In terms of the analogy, trained distractors are darkened through CM training and the new targets stand out from the background of darkened distractors. The strong negative transfer effects that occur when targets and distractors are reversed (Shiffrin & Schneider, 1977, Experiment 1; Prinz, 1979) would result from the need to counteract: a) context inhibition of target stimuli, which were previously distractors, and b) context excitation of distractor stimuli, which were previously targets.

The lack of practice effects of VM training with well learned stimulus sets is consistent with the context activation hypothesis. In a VM training condition, a stimulus that is a target on one trial may be a distractor on the next. To the extent that all relevant nodes are searched for equally in a relatively stable context, there can be no differential activation between the nodes. Hence, there is no net change in the comparison process (of targets and distractors) across trials. In a visual analogy, there would be little benefit from brightening all the stimuli in an experiment. A comparison process which is determined by relative activation of target versus distractor elements would show no changes with practice. As would be predicted from the context activation hypothesis, as the degree of consistency decreases there is less benefit for practice (Schneider & Fisk, 1982b).

Assuming context links are strengthened during CM practice, which links (Figure 8, links _g_, _h_, or _j_) are strengthened? The lack of effect of the number of exemplars in the category search set (Experiment 1a) and the high positive transfer of CM category training to new exemplars of the trained category (Experiments 1b, 2b) suggest that the primary strengthening is between context and the semantic category nodes (Figure 8, link _h_). The better performance on old CM trained (4) words relative to the CM trained (8) words (Experiment 1b) can be interpreted as due to greater context activation of the CM trained (4) words (which had twice as many training detections per word than the CM 8 words). This result suggests that there may be some strengthening of experimental context to word level links (Figure 8, link _g_). The present experiments do not assess whether there is a strengthening of the context to response links (Figure 8, link _j_). However, we have observed what appears to be positive transfer between experiments that utilize the same response procedure. These observations suggest that there is some strengthening of the context to response links. It is also possible that context nodes activate the control nodes which in turn activate the information nodes (e.g., context activates the "category search" and "motor priming" nodes which in turn activate links _a_, _b_, and _f_ in Figure 8).[3]

Previously reported data support a context activation hypothesis rather than simply a reduction in the activation threshold for target nodes. Both hypotheses make similar predictions except that a reduction in activation threshold would predict that CM practice would transfer to all contexts. The data however suggest that transfer is substantially context dependent. First, in general CM trained subjects do not report that target stimuli attract attention outside of the experimental situation. There is one reported instance of extra-experimental interference effects from extended CM letter search training. The subject reported difficulty reading for an hour or two after experimental sessions because the letter "E", a member of her search set, would appear to pop out of the text she was trying to read (Shiffrin & Schneider, 1977, pp. 153). The extra-experimental attraction effect typically dissipated within two hours. Of the hundreds of subjects we have trained in CM experiments we have had only two subjects report CM targets attracting attention outside of the laboratory. Second, in many dual task experiments, we have found that subjects typically require several hours of training to re-enable an automatic process in a changed experimental situation (see discussion, Schneider & Fisk, 1982a,b). Experiment 2a (Figure 5) illustrates the typical finding. When subjects begin dual task search the CM detection accuracy drops to VM levels. If CM training (1755 trials) resulted in a substantial lowering of the activation threshold in any context, one would expect better detection in any situation where target stimuli were unchanged. If CM training results in context activation of a node, the benefit for CM training would reduce as the experimental context or the target stimuli changed. The addition of the VM digit search in Experiment 2a changed both the visual displays and the internal processing of the subject but not the CM target stimuli. One might interpret such changes as substantial alterations in context which result in a reduction in CM detection performance. Much more research is needed, but the current evidence favors the context activation hypothesis.

The data suggest that _context provides a filter on the processing system via lowering the activation requirements of target stimuli and increasing the activation requirements for distractor stimuli_. Consistent with the context filter hypothesis, extended practice causes CM target stimuli to "pop out" of the perceptual field and distractor stimuli to fade into the background. In CM search conditions when letters are rapidly presented (e.g., Schneider & Shiffrin, 1977) subjects often comment that the target letter "freezes" o the display and the distractors are just a background haze. The abili'y of previously trained CM targets to attract attention even when the subject tries to ignore them (Shiffrin & Schneider, 1977, Experiment 4d; Ostrey, Moray & Marks, 1976) and the ability of subjects to detect the CM targets when engaged in a high workload primary task (Schneider & Fisk, 1982a; Fisk & Schneider, in press; and above) support the proposal of strong selective filtering.

The context activation hypothesis can predict the major phenomena associated with VM and CM search. We are developing a production activation simulation model of these effects. The following comments are intended to give the reader an overview of the effects of a context activated filter. There are four major phenomena to be accounted for. First, why is VM search slow and serial? We assume that in order to respond quickly, subjects respond whenever any category exceeds its activation threshold. If the subject makes a parallel comparison it is quite likely that the activation of a target category (e.g., the activation of the "color category" resulting from the joint activation of "color category search" and the word "RED") would be less than the activation of possible distractor categories (e.g., the activation of the "animal category" resulting from the "color category search" and the parallel activation of the distractors "dog", "bear", and "lion"). To maintain accuracy the subject could (through control processing) selectively enhance (scan) individual words. If words are sequentially activated, the category activation resulting from any target word and the category search node (e.g., "RED" and "color category search") will be greater than that resulting from any single distractor and the category search node (e.g., "dog" and "color category search"). The resulting process would be serial and show few false alarms (see Schneider & Shiffrin, 1977).

The second phenomenon is that processing becomes fast and parallel with CM practice. If we assume that context excites target nodes and inhibits distractors, the activation threshold for category nodes can be set (after sufficient CM practice) so that sequential comparison of the words is no longer necessary. The parallel activation of distractors would not be a problem because the distractor categories are inhibited by the context. Referring to our visual search analogy the subject attends only to the bright target stimuli, not processing any of the distractors. Thus, the comparison process could

become fast and parallel. One would also predict that as the stimuli become more confusable or degraded there would be many false alarms. The data support this prediction showing a nearly symmetric trade-off between hits and false alarms in CM search (see Schneider & Shiffrin, 1977, Experiment 1).

The third phenomenon is the lack of control that subjects show when trying to ignore previously trained CM stimuli (Ostrey et al, 1976; Shiffrin & Schneider, 1977, Experiment 4d). If a context activated filter is tuned to activate previous CM targets in STS, the presentation of a previous CM target would interfere (due to high activation of the CM node) with other processing. The subject would have very little control of the context activated filter because the experimental situation precludes changing the context (e.g., the subject's short-term memory capacity is typically consumed by the experimental task; the subject's physiological state and emotional state are stable; etc.).

The fourth phenomenon is the reduction of processing load with CM search practice but not VM practice. We have shown that it is possible to concurrently perform a CM and a VM search task with little if any decrement (Experiment 2a, see also Schneider & Fisk, 1982a; Fisk & Schneider, in press). If context activation (through links g, h, and i, Figure 8) can substitute for control process activation (links a, b, and f, Figure 8) there is no need to maintain the control process nodes (e.g., "category search" and "motor priming") in STS. Thus searching for CM targets can be done at no cost. However there will be a load associated with the actual detecting target stimuli (Duncan, 1980; Ostrey et al, 1976; Schneider & Shiffrin, 1977). In contrast to CM search, VM practice does not substantially reduce processing load (Experiment 2a, see also Schneider & Fisk, 1982a; Fisk & Schneider, in press). Since context activation can not be rapidly altered from trial to trial, context activation can not substitute for control process activation in VM search. The requirement to maintain control process activation results in substantial processing load even after extended practice.

A context tuned semantic filter could have substantial benefits and costs in "real world" information processing. The filter would selectively pass information into STS. By simply sitting in the driver's seat of an automobile with the intention to drive, the human processing system might be tuned at feature, semantic, and motor process levels. Thus tuned, the system would pass only driving related information. There would be no need to consciously check for the presence of any of the hundreds of driving relevant stimuli that could occur at any instant. Under high workload conditions, the situational context filter would pass into STS only those stimuli which were consistently attended to in the past. The benefit of such a filter is that most of stimuli critical for driving would become active in STS even under high workload. Experiment 2b (see Figure 7) demonstrated that even under very high workload 97% of the previously attended words passed through the filter, whereas only 45% of the words new to the situation passed through. The cost of such a filter is that it will pass stimuli into STS even when there is no intention to attend to the stimuli. This is illustrated by the difficulty many people have trying to ignore driving-relevant stimuli while riding as a passenger. Those stimuli which are critical for driving are activated in the STS of the passenger. Hence the passenger may "automatically" pause in a conversation when a traffic light changes at a critical moment.

The present results indicate that the filter can be tuned at the semantic level. The existence of semantic level filtering suggests that the "real world" can provide sufficient CM training to produce automatic processes. We typically observe substantial CM/VM differences in 200 trials and have found significant differences in as few as 10 trials (Schneider & Fisk, Note 3). In normal daily life one might consistently process 200 occurrences of a class of stimuli. For example, in an angry emotional state with a spouse, one might consistently attend 200 times to irritating words (e.g., requests to do chores, ego assaults, complaints, etc.). Even if the same words are not repeated, there may be frequent repetitions of the same semantic class. Thereafter if the emotional context is evoked, the filter will be active, selectively passing irritating words into STS. Under high workload, passing any novel information through the filter might be very difficult.

We have only begun to examine context based semantic filtering. The present data lead to the suggestion that semantic filtering can occur and that the filter can produce large quantitative and qualitative effects on behavior (see also Schneider, Dumais, & Shiffrin, in press; Shiffrin & Schneider, 1977; Fisk & Schneider, in press). The filter seems to be activated without consuming any measurable resources. Previous data suggest that subjects have a great deal of difficulty controlling those filters developed through CM training (Shiffrin & Schneider, 1977). Such selective filtering, which is not directly controlled by the subject, could be very beneficial (e.g., driving), but in some circumstances could produce serious misperceptions (e.g., in an emotional argument).

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Footnotes

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[1] During the first four replications it was apparent that subjects were dividing resources between digit detection and category search. It was probably necessary to divide resources in the dual task VM category search to maintain a significant category search hit rate. The between block manipulation was begun on replication five to increase the likelihood of maintaining primary digit performance on the dual task CM category search trials.

[2] It is unclear whether this improvement was due to learning how to search for the trained category or learning strategies to perform any difficult VM category search (i.e., comparing four categories to two display words).

[3] Some available evidence suggests most of the activation is directly to the information nodes without passing through control nodes. There is little benefit for developing VM category search for arbitrary letter sets before beginning CM training (Shiffrin & Schneider, 1977, Experiment 3). Also CM performance improves as a function of detections not searches (Schneider & Fisk, Note 3).

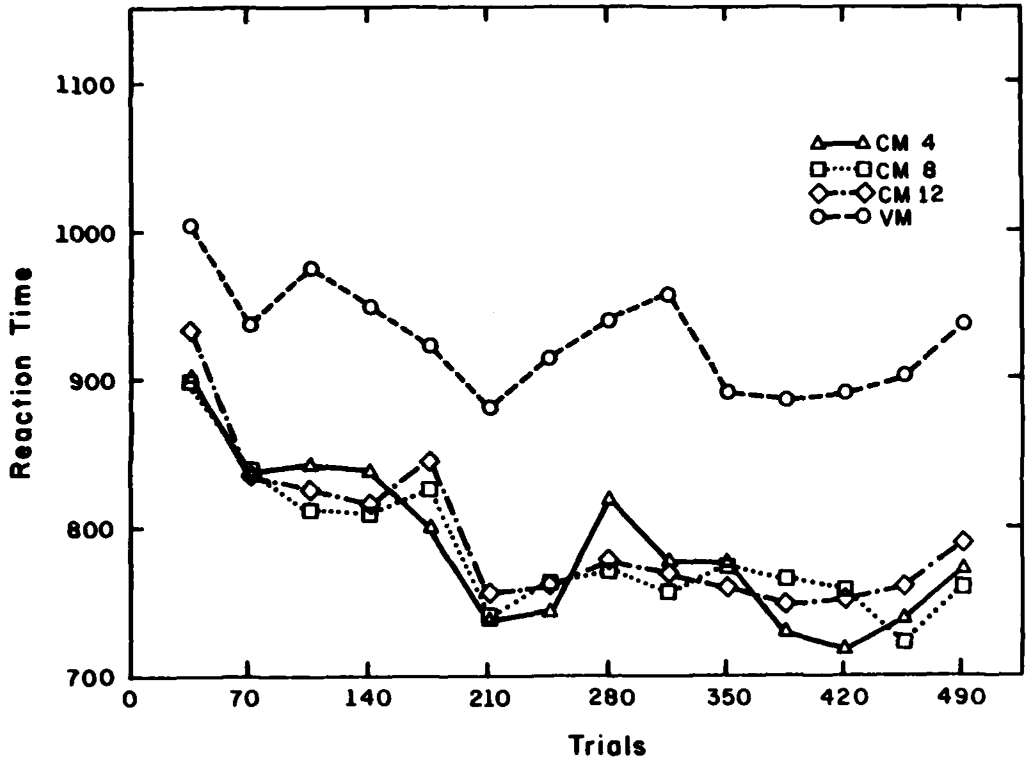

Figure 1. Experiment 1a reaction time as a function of practice. CM4, CM8, CM12 refer to training category set size of 4, 8, and 12, respectively; reaction time is in msec. Each point represents 35 trials per subject.

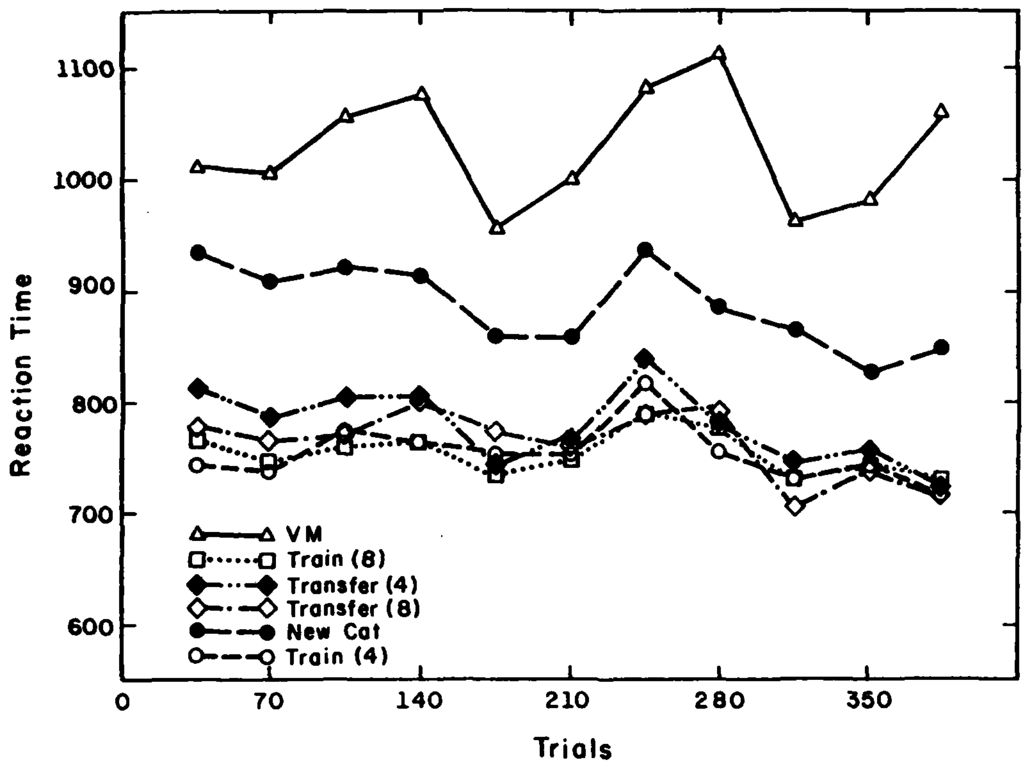

Figure 2. Experiment 1b reaction time transfer of CM category learning. Each point represents 35 trials per subject.

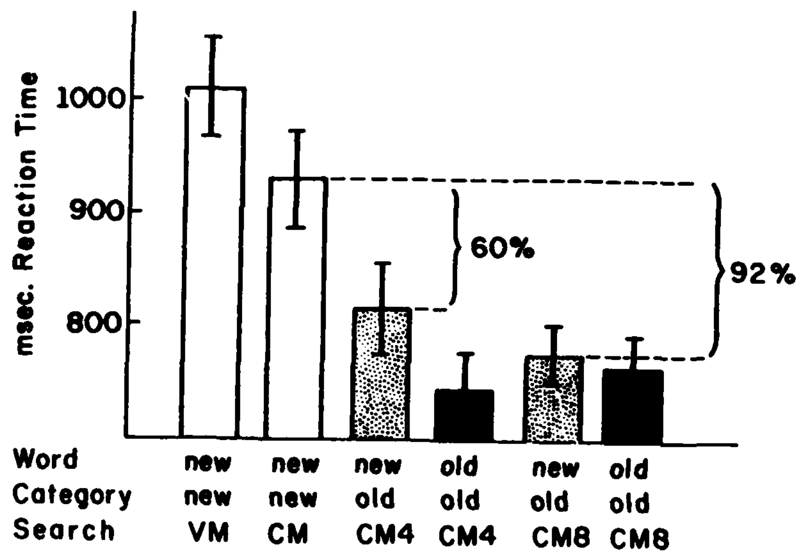

Figure 3. Experiment 1b, first five blocks, illustration of effect. The lines indicate the standard error of the mean.

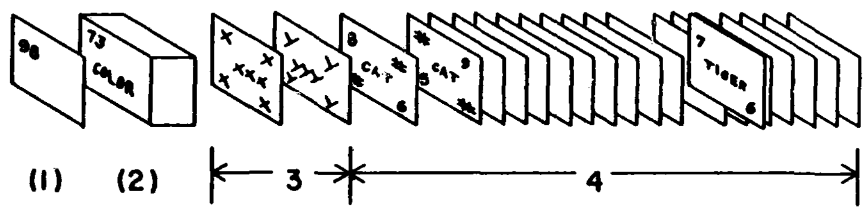

Figure 4. Experimental procedures Experiment 2. Events 1) accuracy feedback; 2) digit memory set and category name; 3) fixation frames; and 4) trial sequence of 20 frames with a digit target.

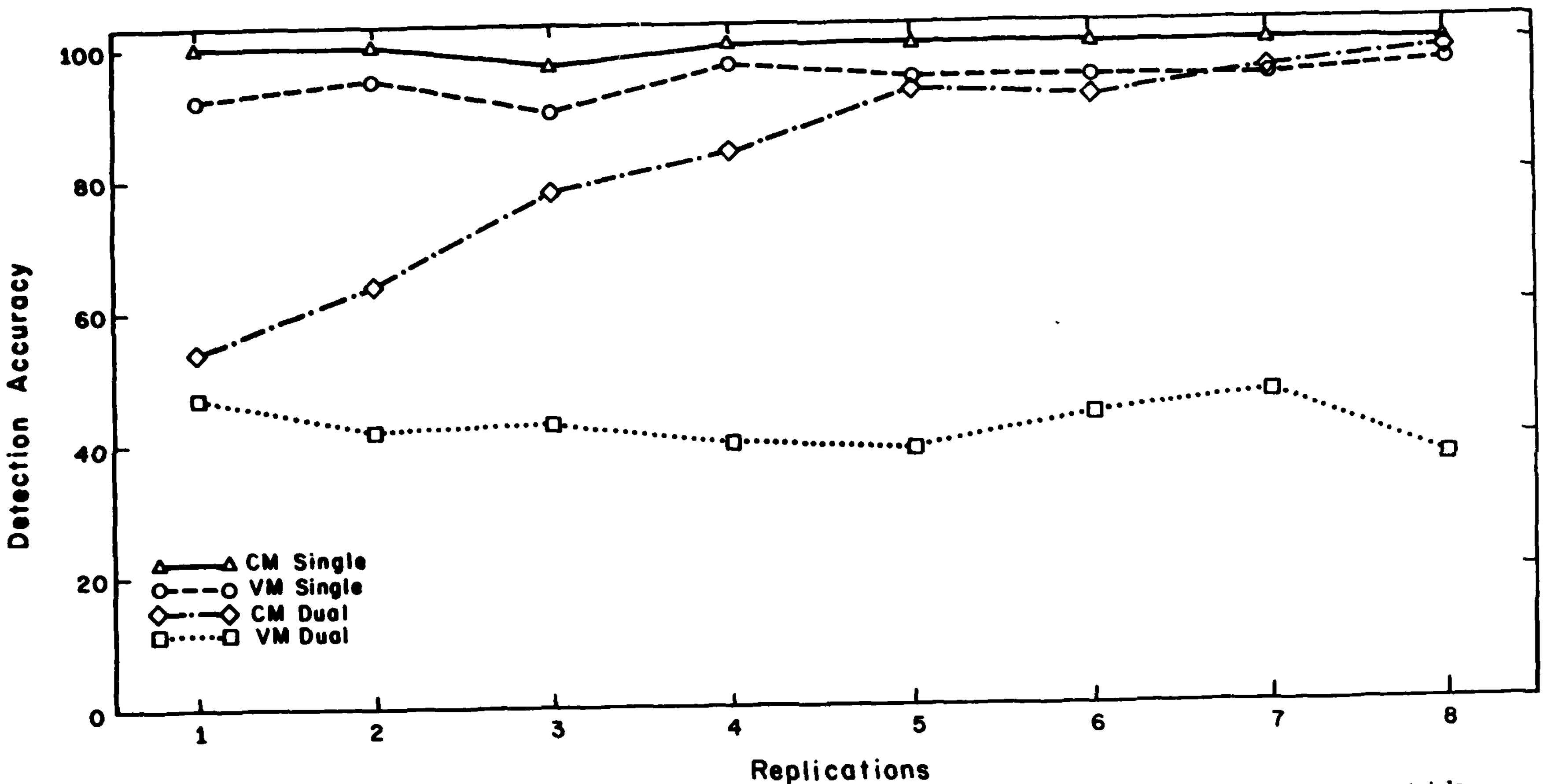

Figure 5. Experiment 2a single and dual task category detection. First four replications, the category search conditions varied between trials. Last four search conditions varied between blocks.

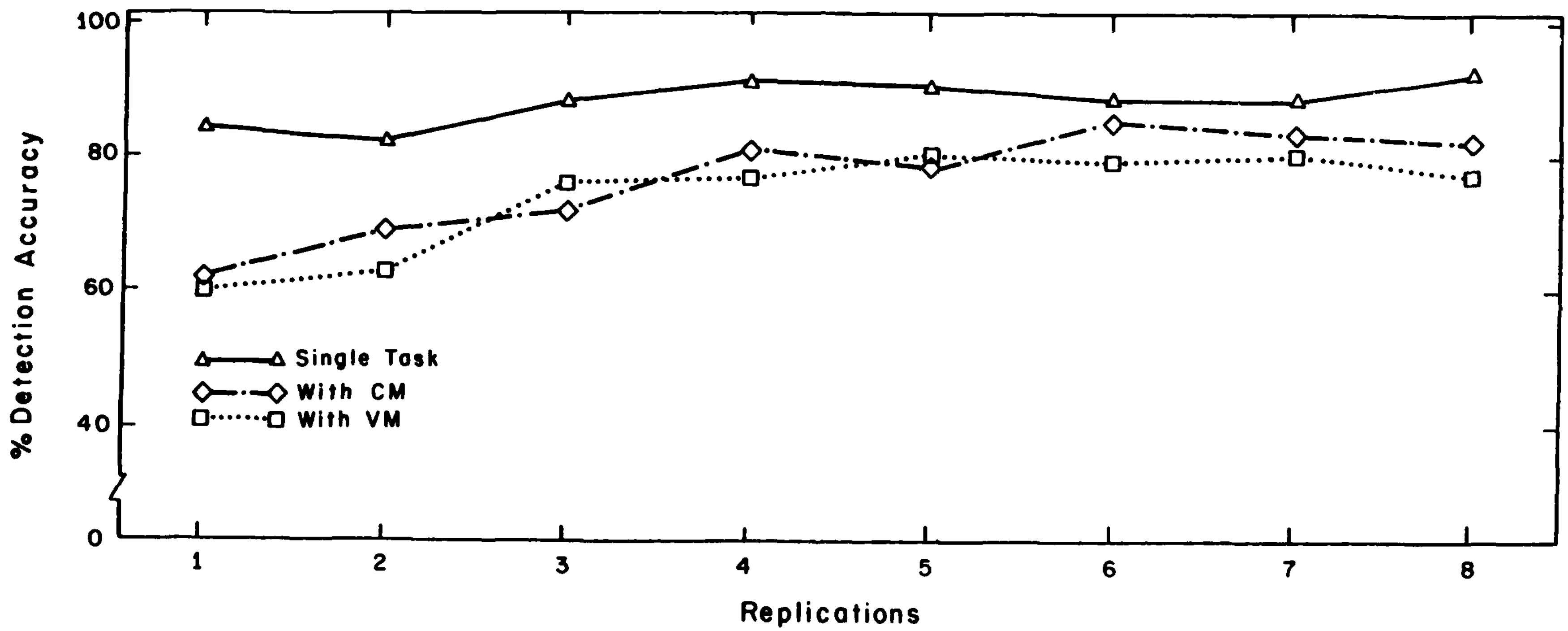

Figure 6. Experiment 2a VM digit search detection. First four replications category search was manipulated between trials, the last four between blocks.

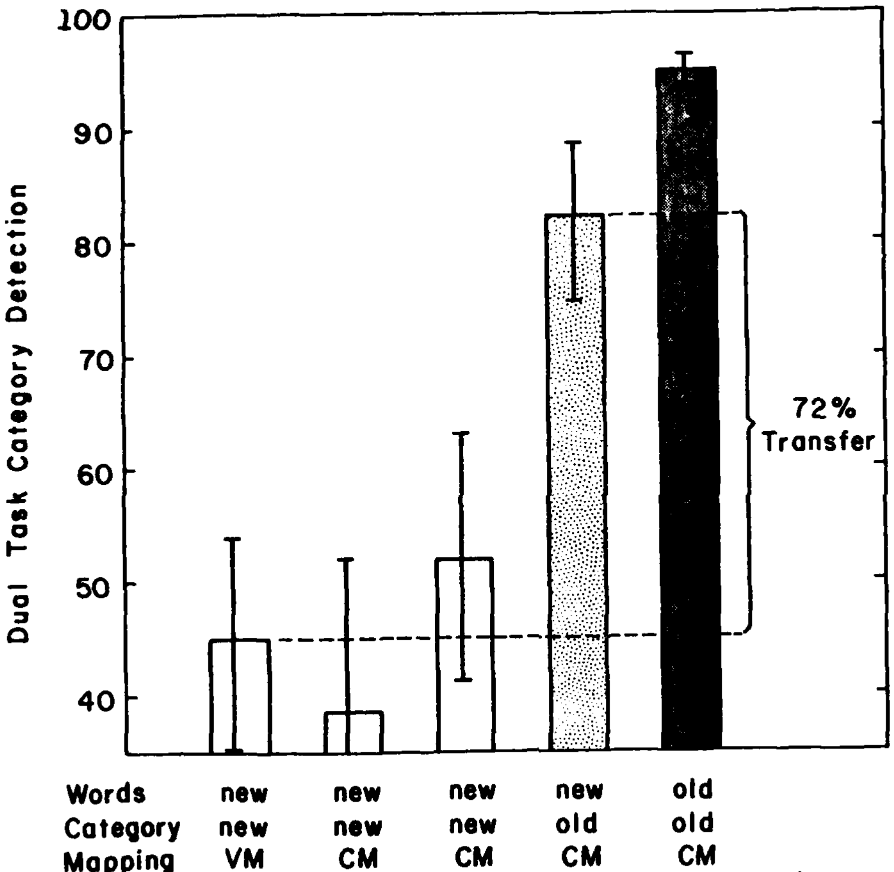

Figure 7. Experiment 2b secondary task category search detection accuracy with concurrent VM digit search. The lines indicate the standard error of the mean.

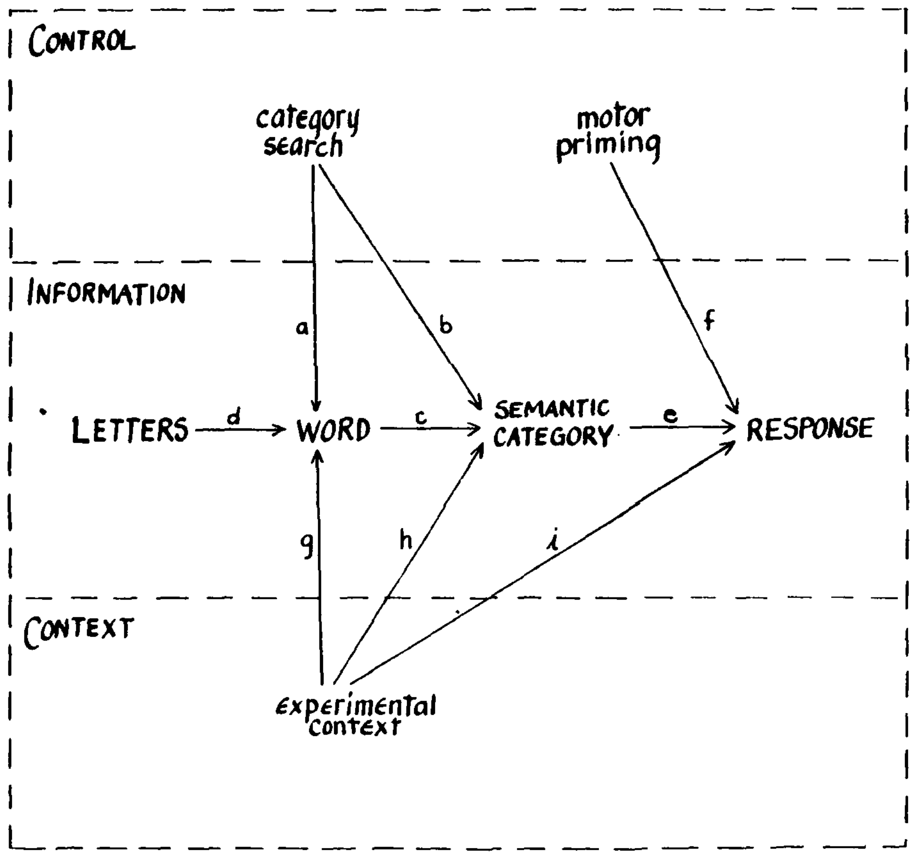

Figure 8. Illustration of different classes of nodes and links which are potential sites of changes with practice.

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